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(71) [Applicant]

[Identification Number] 596098405

[Name] Pechiney RIYUNARIYU

[Address] The France country, 92400 and cool BUBOWA, plus dough Lilith, 6, La Defense and 2, the Tours mana tongue

(72) [Inventor(s)]

[Name] Fabrice EME

[Address] The France country, 38160 and Sun-mull SERAN, RIYU BIESU, 45

(72) [Inventor(s)]

[Name] Philip Luc

[Address] The France country, 63500 and iso WARU, RIYU Eugene GOTEIE, 14

(72) [Inventor(s)]

[Name] Guy-Michelle Ieno

[Address] The France country, 63500 and iso WARU, RE TORADE (with no address)

(74) [Attorney]

[Patent Attorney]

[Name] Kawaguchi Yoshio (outside trinomial)

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Epitome

(57) [Abstract] (*****)

[Technical problem] Like a current alloy, a high static mechanical property and high fatigue resistance are maintained, in the case of a steel plate, the toughness in various directions and the crack rate of the longitudinal-crossing direction and a crossing-longitudinal direction are improved, and it is an aluminum-Cu-Mg mold structure hardening type alloy steel plate with the low residual-stress level after hardening.

[Means for Solution] Thickness exceeds 0.5mm, and is weight %, and a steel plate is element <0.25 besides 3.5<Cu<5.0; 1.0<Mg<2.0; Si<0.25; Fe<0.25; Mn<0.55;. With the aluminium alloy of 0<Mg-2Fe<0.2, depending on the case Plating processing of the field of one side or both is carried out with other aluminium alloys which have 12% or less of overall thickness of the overall thickness of a galvanized steel sheet, on the whole, the rate of recrystallization is higher than 50%, and the difference of the rate of recrystallization of a front face and 1 thickness for 2 minutes is less than 35%.

Moreover, the bending f after processing is the rod located on two base materials which were in the condition hardened and pulled, or hardened and left only die-length l in tension and the condition of having annealed to 1 thickness for 2 minutes $fe < 0.14l.2$

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CLAIMS

[Claim(s)]

[Claim 1] thickness -- 0.5mm -- exceeding -- following presentation (% of the weight): 3.5 -- < -- $Cu < 5.0$ $1.0 < Mg < 2.0$ $Si < 0.25$ $Fe < 0.25$ $Mn < 0.55$ others all element < 0.25
It consists of an AlCuMg aluminium alloy of (however, being $0 < Mn - 2Fe < 0.2$).

Depending on the case Plating processing is carried out with other aluminium alloys whose overall thickness of a plating part is 12% or less of the overall thickness of a galvanized steel sheet. It is in the condition which the rate of recrystallization is higher than 50% on the whole, and the difference of the rate of recrystallization of a front face and 1 thickness for 2 minutes is less than 35%, and was hardened and pulled, or hardens. In tension and the condition of having annealed the bending after processing the rod located on two base materials which left only die-length l to 1 thickness for 2 minutes -- $fe < 0.14$ Steel plate used as $l2$ (f -- bending (micron) -- it is -- e is steel plate thickness (mm) and l is the die length (mm) of a rod).

[Claim 2] $fe < 0.09$ Steel plate according to claim 1 characterized by being $l2$.

[Claim 3] $fe < 0.06$ Steel plate according to claim 2 characterized by being $l2$.

[Claim 4] Thickness is 0.5-3mm and it is $fe < 0.04$. Sheet steel according to claim 3 characterized by being $l2$.

[Claim 5] A steel plate given in any 1 term of claims 1-4 which are $fe < 0.20$.

[Claim 6] A steel plate given in any 1 term of claims 1-5 which are $Si < 0.17$.

[Claim 7] The steel plate according to claim 6 which is $Si < 0.10$.

[Claim 8] A steel plate given in any 1 term of claims 1-7 which are $Cu < 4.0$.

[Claim 9] A steel plate given in any 1 term of claims 1-8 which are $Mg < 1.5$.

[Claim 10] A steel plate given in any 1 term of claims 1-9 characterized by being $Mn < 0.4$.

[Claim 11] It is $< (\text{bending of rod of direction of } L) \ 1.5 \times (\text{bending of the rod of the direction of } TL)$ after processing between the rods into which it was processed in the direction of L , and the direction of TL to 1 thickness for 2 minutes.

A steel plate given in any 1 term of claims 1-10 which show the isotropy of bending which becomes.

[Claim 12] A steel plate given in any 1 term of claims 1-11 characterized by showing the elasticity limit of the direction of TL which exceeds 290MPa(s) in the condition of having hardened and pulled.

[Claim 13] A steel plate given in any 1 term of claims 1-11 which show the elasticity limit of the direction of TL which hardens and exceeds 400MPa(s) in tension and the condition of having annealed.

[Claim 14] A steel plate given in any 1 term of claims 1-11 which show the elasticity limit of the direction of TL which exceeds 270MPa(s) in the condition of having hardened and pulled.

[Claim 15] A steel plate given in any 1 term of claims 1-11 which show the elasticity limit which hardens and exceeds 380MPa(s) in tension and the condition of having annealed.

[Claim 16] A steel plate given in any 1 term of claims 1-15 maximum stress permissible with the given number of cycles indicates fatigue resistance which exceeds 100MPa(s) by 107 cycle 100MPa(s) to be by 105 cycle 295MPa(s) in 104 cycle at 106 cycle 160MPa(s) , respectively.

[Claim 17] A steel plate given in any 1 term of claims 1-16 which show toughness $K1C$ of the direction of $L-T$ where thickness exceeds $35\text{ MPa}\sqrt{\text{cm}}$ where it exceeded 20mm and it is hardened and pulled.

[Claim 18] A steel plate given in any 1 term of claims 1-17 which show toughness $K1C$ of the direction of $T-L$ where thickness exceeds $32\text{ MPa}\sqrt{\text{cm}}$ where it exceeded 20mm and it is hardened and pulled.

[Claim 19] The steel plate according to claim 17 in which toughness $K1C$ of the direction of $L-T$ which exceeds $40\text{ MPa}\sqrt{\text{cm}}$ in the condition of having hardened and pulled is shown.

[Claim 20] The steel plate according to claim 18 in which toughness $K1C$ of the direction of $T-L$ which exceeds $35\text{ MPa}\sqrt{\text{cm}}$ in the condition of having hardened and pulled is shown.

[Claim 21] A steel plate given in any 1 term of claims 17-20 which show toughness K1C of the direction of S-L where thickness exceeds 35mm and exceeds 22 MPa $\sqrt{\text{m}}$.

[Claim 22] The steel plate according to claim 21 in which the toughness of the direction of S-L exceeding 24 MPa $\sqrt{\text{m}}$ is shown.

[Claim 23] A steel plate given in any 1 term of claims 1-16 which show toughness K1C of the direction of L-T where thickness exceeds and hardens 20mm and exceeds 28 MPa $\sqrt{\text{m}}$ in tension and the condition of having annealed.

[Claim 24] A steel plate given in any 1 term of claims 1-16 which show toughness K1C of the direction of T-L where thickness exceeds and hardens 20mm and exceeds 25 MPa $\sqrt{\text{m}}$ in tension and the condition of having annealed.

[Claim 25] The steel plate according to claim 23 in which toughness K1C of the direction of L-T exceeding 32 MPa $\sqrt{\text{m}}$ is shown.

[Claim 26] The steel plate according to claim 24 in which toughness K1C of the direction of T-L exceeding 28 MPa $\sqrt{\text{m}}$ is shown.

[Claim 27] A steel plate given in any 1 term of claims 23-26 which show toughness K1C of the direction of S-L where thickness exceeds and hardens 35mm and exceeds 18 MPa $\sqrt{\text{m}}$ in tension and the condition of having annealed.

[Claim 28] The steel plate according to claim 27 in which toughness K1C of the direction of S-L which hardens and exceeds 20 MPa $\sqrt{\text{m}}$ in tension and the condition of having annealed is shown.

[Claim 29] A steel plate given in any 1 term of claims 1-16 which thickness exceeds 20mm and show [$\Delta K=10$ MPa $\sqrt{\text{m}}$] crack rate da/dN of under 2×10^{-3} mm / cycle by 6×10^{-4} mm/cycle $\Delta K=25$ MPa $\sqrt{\text{m}}$ by 5×10^{-5} mm/cycle $\Delta K=15$ MPa $\sqrt{\text{m}}$ at 10^{-4} mm/cycle $\Delta K=20$ MPa $\sqrt{\text{m}}$.

[Claim 30] A steel plate given in any 1 term of claims 1-16 which show the toughness K_{Cb} of the direction of T-L where thickness exceeds 110 MPa $\sqrt{\text{m}}$ by less than 20mm.

[Claim 31] A steel plate given in any 1 term of claims 1-16 whose roughness Ra after chemical machining thickness is less than 6 microns in less than 12mm.

[Claim 32] The steel plate according to claim 31 whose roughness after chemical machining thickness is less than 3 microns in less than 4mm.

[Claim 33] following presentation (% of the weight): -- 3.5 -- < -- Cu<5.01.0<Mg -- < -- 2.0Si<0.25Fe -- < -- 0.25Mn<0.55 others all element <0.25 It consists of an AlCuMg aluminium alloy of (however, being $0 < \text{Mn} - 2\text{Fe} < 0.2$). In the condition of the rate of recrystallization being higher than 50% on the whole, and the difference of the rate of recrystallization of a front face and 1 thickness for 2 minutes being less than 35%, and having hardened, in or the condition of having hardened and annealed The bending f

after processing the rod located on two base materials which left only die-length l to 1 thickness for 2 minutes $f_e < 0.14$ l_2 -- desirable -- $f_e < 0.09$ The extrusion of the alloy used as l_2 (measuring f by the micron, e is the average local thickness of the product in point of measurement, and also measures l by mm), forging, or mold press product.

[Claim 34] The product according to claim 33 in which the elasticity limit $R_{0.2}$ which exceeds 290MPa(s) where stress relieving is hardened and carried out is shown.

[Claim 35] The product according to claim 33 in which the elasticity limit which exceeds 400MPa(s) in the condition of having hardened and carried out stress relieving and having annealed is shown.

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] Especially this invention holding the high static mechanical property (the destruction-proof nature, the elasticity limit, and elongation), the very good damage-proof nature, and the fatigue resistance good in a low crack expansion rate list which are a property suitable for use by aircraft manufacture According to the name of the U.S. aluminum association who shows the residual stress of a low after hardening, it is related with thick [belonging to 2000 series] (thickness $> 12\text{mm}$), inside thickness (3-12mm in thickness), or a steel plate [being thin (0.5-3mm in thickness)]. These steel plates may be used as they are, and may be plated with other aluminium alloys in which for example more good corrosion resistance is shown.

[0002]

[Description of the Prior Art] The residual stress looked at by the structure hardening type aluminum steel plate is produced with hardening which must be performed in order

to give a good mechanical property. If a thermal shock arises by cooling rapidly from an elevated temperature required using an addition element as a solution, very high internal stress will occur.

[0003] Such stress is troublesome in order to cause great deformation at the time of steel plate processing. This phenomenon is frequently seen by aircraft manufacture. In order to reduce such stress, after the various stress relieving (detensionnement) approaches (traction), for example, ****, that internal stress can be reduced, or adjustment compression hardening, it is applied without having a bad influence on the property of a product like [in heat treatment]. Research in this field suited optimizing **** required mainly realizing effective stress relieving or compression actuation.

[0004] Furthermore, the great activity was done about the hardening actuation itself. These activities are done by being immersed in cold water generally or sprinkling cold water, and the cooling rate obtained by doing in this way has not often been [it is quick and]. Each alloy has a critical hardening rate, if a cooling rate is slower than this critical velocity, the solid solution will decompose and a final mechanical property and damage-proof nature will actually fall sharply. Therefore, although it must harden more quickly than this critical velocity, if cooling becomes strong, since it is a well-known thing, even if it makes it quick too much, it is useless [that internal stress is improved].

[0005] The compromise for optimizing hardening of a steel plate as cooling which stops internal stress to the minimum is also must be found out avoiding the fall of a final mechanical property in this way.

[0006]

[Problem(s) to be Solved by the Invention] The ** which does not change at all the procedure in which this invention is usually used for hardening or stress relieving, Maintaining a high static mechanical property (destruction-proof nature, an elasticity limit, and elongation) and high fatigue resistance as well as the case of a current alloy, and improving the toughness in various directions, and the crack rate of the longitudinal - crossing (L-T) direction and the direction of crossing-straight side (T-L) in the case of a steel plate It aims at lowering the residual-stress level after hardening of an aluminum-Cu-Mg mold structure hardening type alloy steel plate.

[0007]

[Means for Solving the Problem] this invention -- thickness -- 0.5mm -- exceeding -- following presentation (% of the weight): 3.5 -- < -- Cu<5.0 1.0<Mg -- < -- 2.0 Si<0.25 Fe -- < -- 0.25 Mn<0.55 others all element <0.25 It consists of an aluminium alloy of (however, being 0<Mn-2Fe<0.2). Depending on the case Plating processing of the field of one side or both is carried out with other aluminium alloys which have 12% or less of overall thickness of the overall thickness of a galvanized steel sheet. It is in the condition which

the rate of recrystallization is higher than 50% on the whole, and the difference of the rate of recrystallization of a front face and 1 thickness for 2 minutes is less than 35%, and was hardened and pulled, or hardens. In tension and the condition of having annealed the bending f after processing the rod located on two base materials which left only die-length l to 1 thickness for 2 minutes -- $fe < 0.14 l_2$ -- preferably $fe < 0.09 l_2$ -- further -- desirable -- $fe < 0.06$ The steel plate used as l_2 (measuring f by the micron, e is steel plate thickness (mm) and also measures l by mm) is offered.

[0008] Bending is $fe < 0.04$ when thickness is less than 3mm sheet steel. It is set to l_2 .

[0009] Less than 0.4% is [copper / magnesium / manganese] desirable [iron / silicon / less than 4% / less than 1.5%] less than 0.17% and less than 0.10 more% less than 0.2%.

[0010] A steel plate shows the elasticity limit $R_{0.2}$ which exceeds 290MPa(s) to a crossing longitudinal direction in the condition of having hardened and which exceeds 400MPa(s) where tempering is hardened and carried out. For example, in the case of a galvanized steel sheet which is used for manufacture of an aircraft fuselage, generally, an aluminum content carries out plating processing of both sides with the aluminium alloy in which little good corrosion resistance is shown. Each deposit will occupy 4 - 6% of overall thickness with the thinnest steel plate, and can become by 2 - 4% of overall thickness with the steel plate with which thickness exceeds 1.6mm, and it will be said that the overall thickness of a plating part does not exceed 12% of steel plate overall thickness by any means. The elasticity limit of the direction of L-T and the direction of T-L exceeds 270MPa and 380MPa(s), respectively.

[0011] When a steel plate is measured on a flat test piece as a ratio $R = 0.1$ of stress concentration factor $K_t = 2.3$ and minimum stress pair maximum stress, stress permissible with the given number of cycles shows fatigue resistance which exceeds 100MPa(s) by 107 cycle 100MPa(s) by 105 cycle 295MPa(s) in 104 cycle at 106 cycle 160MPa(s).

[0012] The steel plate which thickness exceeds 20mm and Fe content becomes from less than 0.2% of alloy is in the condition hardened and pulled, and the toughness measured in the direction of L-T and the direction of T-L by flat-surface deformation criticality stress intensity coefficient (facteur d'intensite de contrainte critique en deformation plane) K_{Ic} exceeds 35 MPa \sqrt{m} and 32 MPa \sqrt{m} , respectively, and it exceeds 40 MPa \sqrt{m} and 35 MPa \sqrt{m} preferably.

[0013] Hardening, in tension and the condition of having annealed, these toughness exceeds 28 MPa \sqrt{m} and 25 MPa \sqrt{m} , respectively, and exceeds 32 MPa \sqrt{m} and 28 MPa \sqrt{m} preferably.

[0014] In the condition of having hardened and pulled, 22 MPa \sqrt{m} is exceeded, and

the toughness measured in the direction of S-L with the steel plate with which thickness exceeds 35mm exceeds and hardens 24 MParootm preferably, by tension and the condition of having annealed, it exceeds 18 MParootm and exceeds 20 MParootm preferably.

[0015] Crack rate da/dn of a steel plate of the direction of L-T of $R=0.1$ and the direction of T-L is [in $\Delta K=10$ MParootm / in 5×10^{-5} mm/cycle $\Delta K=15$ MParootm] under 2×10^{-3} mm / cycle in 6×10^{-4} mm/cycle $\Delta K=25$ MParootm further at 10^{-4} mm/cycle $\Delta K=20$ MParootm.

[0016] The orientation code of L-T, T-L, and the direction of S-L is defined as ASTM specification E399 about the toughness trial of a metallic material.

[0017] The toughness to which thickness measured the less than 20mm steel plate in the direction of T-L with the plane stress criticality stress intensity coefficient (facteur d'intensite de contrainte critique en contrainte plane) K_{cb} exceeds 110 MParootm. Toughness measures width of face of 405mm, notch die length of 100mm, and thickness with a test piece equal to the thickness of a steel plate (6mm or less and 6mm or more). This thickness is obtained after symmetrical surface finish (surfacage symetrique).

[0018]

[Embodiment of the Invention] this invention persons searched for reduction of residual stress contrary to the direction of research of the conventional technique in respect of the metal engineering parameter which intervenes before hardening.

[0019] Possibility of eliminating the existing alloy constituent containing main alloying elements (Cu and Mg) in order to have to acquire a high mechanical property is very low. When this invention persons groped for modification of the content of additional trace elements and the weight ratio of iron and manganese became $Mn < 0.55\%$, $Fe < 0.25\%$, and $0 < Mn - 2Fe < 0.2\%$, the knowledge of the best result being obtained about reduction of residual stress, therefore processing stability was carried out.

[0020] This means that the content of manganese must also decrease, if an iron content decreases. Although the iron content of an aluminum-Cu alloy is in the inclination to fall constantly so that transition for these 20 years of the constituent registered into the aluminum association about alloys 2024, 2124, 2224, and 2324 may show, the content of Mn is not changing with these constituents. If hot rolling outlet temperature is adjusted, with the constituent of this invention, it will recrystallize widely, the rate of recrystallization will always exceed 50%, and the fine structure a steel plate side and whose recrystallization inclination based on steel plates are always less than 35% will be acquired. In the case of a steel plate, especially this is remarkable, is 1 thickness for 2 minutes, and has the structure which main elementary composition recrystallized

more clearly rather than the steel plate of the same conventional technique.

[0021] Contrary to anticipation of the metal engineering expert of a high tensile aluminum alloy, the content of Mn which structure recrystallizes very much in this way, and participates in hardening of an alloy since it is detailed precipitate aluminum₂OCu₂Mn₃ and AlMn₆ is not influenced with the serious static mechanical property of a steel plate at least. Although it felt it uneasy to also reduce fatigue resistance moreover, it is checked that fatigue resistance is held.

[0022] Furthermore, the toughness which will be measured by flat-surface deformation criticality stress intensity coefficient K_{1c} according to ASTM specification E399 if structure recrystallizes [this invention persons] widely contrary to anticipation in the case of the steel plate to which thickness exceeds 20mm checked rising in all directions.

[0023] These steel plates that finally have the structure which recrystallized widely have the crack rate of the direction of L-T, and the direction of T-L slower than the steel plate with the same main elementary composition of the conventional technique. In these steel plates, a very advantageous compromise can be found out between a static mechanical property and damage-proof nature (toughness and crack rate) in this way.

[0024] In the case of sheet steel, contrary to the idea generally accepted that the numerousness of Mn and Fe contents acts in favor of elongation since detailed sediment to manganese equalizes deformation and formation of a deformation band can be restricted, this invention persons checked that the constituent of this invention acted on plus at the elongation of the crossing-longitudinal direction of a steel plate. Generally it was a metallurgist's idea that similarly the structure accepted noting that it recrystallizes very much, and a particle is fine and useful on elongation, if Mn and Fe content are rather made [many] in the case of sheet steel or an inside steel plate is acquired.

[0025] If a Mn-2Fe content is less than the threshold which is 0.2% in this way, processing stability not only becomes good, but in sheet steel or a steel plate, residual stress will decline and the whole operating property will become advantageous especially by aircraft manufacture. However, a mechanical property is spoiled, and since it is checked that there is nothing, it is not desirable [an additional advantage], even if internal stress will decline, if a Mn-2Fe value becomes negative to become negative.

[0026] For the steel plate of this invention, the bending f which measured after processing the rod located on two base materials which are in the condition hardened and pulled, or hardened, and left only die-length l in tension and the condition annealed to 1 thickness for 2 minutes is $f_e < 0.14$. The residual stress of the level which is set to

l2 (f is measured by the micron and thickness e and die-length l of a steel plate are expressed with mm) is shown.

[0027] This bending is measured by the following approaches. Two rods are sampled out of the steel plate of thickness e. One side calls the rod of the direction of L, and it has thickness e of die-length l of the longitudinal direction (the direction of L) of a steel plate] b, width of face of 25mm of the cross direction (the direction of TL) of a steel plate, and the solid thickness (the direction of TC) of a steel plate, and another side is called the rod of the direction of TL, and has the 25mm of the directions of L, the direction b of TL, and the direction e of TC.

[0028] Each rod is processed to 1 thickness for 2 minutes, and bending of 1 die length for 2 minutes of a rod is measured. This bending shows the internal stress level of a steel plate, and the non-deformans to processing.

[0029] In the case of the steel plate to which thickness exceeds 20mm, die-length b of a rod is $5e+20\text{mm}$. Processing is gradual machining with about 2mm pass.

[0030] Measurement of bending of 1 die length for 2 minutes is placed between two knives which left only $l=5e$, is the center of the rod which projected 10mm from the both sides of this knife, and is performed using the comparator of a micron unit.

[0031] The thickness of die-length l which die-length b of a rod is 400mm, and is used for measurement of bending with a less than 20mm steel plate is 300 fixedmm.

[0032] By the thickness of 8-20mm, processing is machining with 1mm pass. If set to less than 8mm, processing will become a chemical thing under soda bath. The whole surface of a rod is protected using the flexible-plastics mask removed before a trial. A sample is taken out from an attack bath and thickness is inspected every 15 minutes.

[0033] With less than 2mm sheet steel, approaches differ [thickness] slightly. Bending can be measured with a less than 0.5mm error, eliminating the effect of the force of the proper weight of a rod, or a comparator to bending of 1 die length for 2 minutes, if the milli grid sheet of one sheet is placed on a horizontal plane, a rod is placed on it in the direction of straight side (die length, 1 thickness for 2 minutes) and bending is measured.

[0034] this invention persons checked further that the isotropy of deformation might be improved. In this way, the bending measured in the longitudinal direction and the crossing direction of rolling on the rod in the steel plate of this invention is $<(\text{bending of direction of L}) 1.5 (\text{bending of the direction of TL})$.

It becomes.

[0035] In less than 12mm sheet steel and an inside steel plate, it is checked that the roughness after chemical machining is [less than 6 microns and thickness] less than 3 microns in a less than 4mm steel plate for thickness.

[0036] This invention is further applied to aluminium alloy products other than a steel plate, for example, extrusion, forging, or a mold press product. In this case, thickness e of a rod is the local thickness of a test piece. If this thickness is not fixed, surface finish can be performed in order to obtain the rod of fixed thickness for bending measurement.

[0037] It has the elasticity limit which exceeds 290MPa(s) where it hardened these products and stress relieving is carried out and which exceeds 400MPa(s) in the condition of having hardened and carried out stress relieving and having annealed.

[0038]

[Example] The comparison result indicated in the following three examples is shown in drawing 1 - drawing 10 so that an improvement of the property brought about with the steel plate of this invention may be shown.

[0039] According to an example 1 aluminum association's nomenclature, semi-continuous casting of the plate of the various alloys of 2024 molds was carried out several times. All plates are the same dimensions and were cast according to the same procedure. The reheating accompanied by the conventional processing of a single string of casting, next a steel plate, i.e., homogenization, hot rolling, solution-izing, cold-water hardening by water spray, specification EN Aging at 1.5 - 3% of adjustment **** and the room temperature based on 515 was performed. Thus, according to an aluminum association's nomenclature, the steel plate of T351 condition is obtained by 55mm in thickness. The presentation of a casting alloy is : [0040] which was as follows.

[Table 1]

| 合金 | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Zr |
|----|------|------|------|------|------|-------|------|------|-------|
| A1 | 0,11 | 0,23 | 4,32 | 0,63 | 1,43 | 0,022 | 0,11 | 0,02 | 0,014 |
| A2 | 0,08 | 0,17 | 4,52 | 0,52 | 1,40 | 0,008 | 0,10 | 0,02 | 0,002 |
| A3 | 0,08 | 0,16 | 4,48 | 0,51 | 1,41 | 0,007 | 0,08 | 0,02 | 0,002 |
| A4 | 0,08 | 0,15 | 4,32 | 0,37 | 1,29 | 0,005 | 0,05 | 0,02 | 0,001 |
| A5 | 0,08 | 0,16 | 4,44 | 0,54 | 1,30 | 0,008 | 0,08 | 0,02 | 0,002 |

[0041] Measurement of the following [the above-mentioned steel plate] was carried out. : - Bending after processing based on an above-mentioned approach. It is checked that the bending produced with the alloy A2 of this invention, A3, and the steel plate of A4 is smaller than the alloy A1 which is not contained in this invention and the steel plate of A5 in especially the direction of L.

[0042] - The static mechanical property in the direction of TL (rolling crossing), and the direction of TC (short crossing) (destruction-proof nature Rm, 0.2% elasticity limit R0.2, and fracture point elongation A). The test piece of the direction of TL is sampled by the quadrant thickness of a steel plate.

[0043] - Toughness measured in L-T, T-L, and the direction of S-L based on ASTM specification E399 and B645. An improvement is shown in drawing 4 -6.

[0044] - The rate of surface recrystallization of the quadrant thickness measured from a microscopic inspection, and 1 thickness for 2 minutes. The above-mentioned whole result is shown in Table 1.

[0045] - The fatigue life time measured in the direction of L, and the direction of T-L according to ASTM specification E466 about a sample 3 (alloy A1 which is not contained in this invention), and a sample 9 (alloy A4 of this invention). A test piece is a 3mm flat test piece sampled by the quadrant thickness of a steel plate. Stress concentration factor $K_t=2.3$ can be used by processing a central hole. The ratio R0.1 of minimum stress pair maximum stress is used. The result shown in Table 2 is almost the same in the direction of L, and the direction of TL. It turns out that a result is shown in drawing 7 and the result is very alike with these two sorts of alloys.

[0046] - It is crack rate da/dn which sets a ratio R to 0.1 about a sample 3 and a sample 9, and measures delta K value in T-L and the direction of L-T as 10 - 25 MPa \sqrt{m} according to ASTM specification E647 similarly. A test piece is the test piece CT sampled by the quadrant thickness of a steel plate. It is 35. The result shown in Table 3 is very alike in both directions. Drawing 8 shows that the sample 9 has a crack rate slower than a sample 3.

[0047] Semi-continuous casting of the plate of the alloy of example 22024 mold was carried out, and this was given to aging at a series of conventional processings of a plating thin steel plate, i.e., reheating, the coincidence hot rolling (colaminage a chaud) using two 1070 alloy-plate (couverture) steel plates, cold rolling, solution-izing, cold-water hardening, mirror plane finishing, adjustment ****, and a room temperature. Thus, the steel plate in T351 condition with a thickness of 1.6mm that the plating thickness of each field is equivalent to 5% of steel plate thickness is obtained.

[0048] The presentation of 2024 alloys is : [0049] which was as follows.

[Table 2]

| 合金 | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Zr |
|----|-------|------|------|------|------|-------|-------|-------|-------|
| A6 | 0,09 | 0,19 | 4,38 | 0,63 | 1,50 | 0,013 | 0,10 | 0,024 | 0,014 |
| A7 | 0,079 | 0,17 | 4,36 | 0,52 | 1,30 | 0,012 | 0,013 | 0,022 | |

[0050] Measurement of the following [the above-mentioned steel plate] was carried out. : - Bending after processing based on an above-mentioned approach. Compared with the alloy A6 which is not contained in this invention with the alloy A7 of this invention, these bending decreases clearly in the direction of L, and the direction of TL, and it is relational-expression $fe < 0.04$. It is checked that I2 is realized.

[0051] - The static mechanical property in the direction of TL (average of two test pieces sampled in the rolling crossing direction, and four alloy steel plates).

[0052] A result is shown in Table 4. In drawing 9 , it turns out that processing bending

decreases [that the elongation of the direction of TL of an alloy A7 is improved compared with A6] among these same alloys by drawing 10 .

[0053] According to the casting procedure of example 3 identities, semi-continuous casting of the plate of the same dimension was carried out. These plates were given to aging at a series of conventional processings of an inside steel plate, i.e., reheating, hot rolling, solution-izing, cold-water hardening, adjustment ****, and a room temperature. Thus, the following presentations : [0054]

[Table 3]

| 合金 | Si | Fe | Cu | Mn | Mg | Cr | Ni | Zn | Ti | Zr |
|----|------|------|------|------|------|-------|-------|------|------|-------|
| A8 | 0,08 | 0,17 | 4,45 | 0,53 | 1,46 | 0,007 | 0,005 | 0,06 | 0,02 | 0,002 |

[0055] since -- the steel plate of T351 becoming condition with a thickness of 12mm is obtained.

[0056] Measurement of the following [the above-mentioned steel plate] was carried out. : - Bending after processing based on an above-mentioned approach.

[0057] - The static mechanical property in the direction of TL (rolling crossing).

[0058] - The rate of surface recrystallization in quadrant thickness and 1 thickness for 2 minutes.

[0059] A result is indicated to Table 5 and shown in drawing 11 and drawing 12 .

[0060]

[Table 4]

表 1 :

| 鋼板 | | | 撓み | | 再結晶化 | | | | 機械的性質 | | | | | | | | | 靱性 | | |
|--------|---------|----|-----|-----|------|------|------|-----------------|-------|------|------|-----|------|-----|------|------|------|----|--|--|
| (※70%) | | | % | | | | | | T L | | | T C | | | | | | | | |
| n° | e. (mm) | 合金 | TL | TL | 表面 | 4分の1 | 2分の1 | 表面- 2分の1厚さの差 | Rm | R0.2 | A% | Rm | R0.2 | A% | L-T | T-L | S-L | | | |
| 1 | 55 | A1 | 210 | 120 | | | | | 478 | 351 | 13.6 | 431 | 306 | 5.9 | | | | | | |
| 2 | 55 | " | 231 | 55 | | | | | 468 | 342 | 15.7 | 432 | 306 | 6.1 | | | | | | |
| 3 | 55 | " | 207 | 79 | 79 | 58 | 30 | 49 | 470 | 341 | 15.3 | 432 | 306 | 6.2 | 37.1 | 32.2 | 22.2 | | | |
| 4 | 55 | A2 | 57 | 43 | 99 | 95 | 71 | 28 | 461 | 330 | 16.5 | 419 | 315 | 7 | 44.4 | 38.1 | | | | |
| 5 | 55 | " | 46 | 33 | 100 | 95 | 69 | 31 | 462 | 329 | 17.2 | 417 | 314 | 6.3 | 44 | 40.9 | | | | |
| 6 | 55 | " | 42 | 31 | 100 | 96 | 68 | 32 | 462 | 329 | 16.9 | 422 | 312 | 7.1 | 45.3 | 38.5 | | | | |
| 7 | 55 | A3 | 57 | 62 | 97 | 84 | 63 | 34 | 468 | 343 | 17.7 | 421 | 320 | 5.4 | | | | | | |
| 8 | 55 | " | 100 | 70 | 96 | 68 | 62 | 34 | 481 | 358 | 14.7 | 422 | 315 | 4.9 | 43.2 | 37.2 | 26.1 | | | |
| 9 | 55 | A4 | 49 | 73 | 99 | 93 | 70 | 29 | 463 | 332 | 14.4 | 425 | 299 | 8.5 | 51.8 | 43.8 | 29.6 | | | |
| 10 | 55 | A5 | 156 | 9 | 95 | 82 | 64 | 31 | 470 | 344 | 16.5 | 425 | 312 | 6.1 | | | | | | |
| 11 | 55 | " | 128 | 1 | 96 | 86 | 62 | 34 | 468 | 336 | 17.4 | 418 | 314 | 5.1 | | | | | | |
| 12 | 55 | " | 150 | 25 | 99 | 88 | 70 | 29 | 469 | 338 | 16.1 | 418 | 314 | 6 | | | | | | |

Rm, R0.2 (MP a.)

韌性 (MP a√m)

[0061]

[Table 5]

表 2 : 鋼板 3 及び 9 の耐疲労性の結果
($K_t=2.3$, $R=0.1$)

| 鋼板 3 | | | 鋼板 9 | | |
|------|---------------|-----------------|------|---------------|-----------------|
| 方向 | 最大応力 (MPa) | 存続時間 (サイクル数) | 方向 | 最大応力 (MPa) | 存続時間 (サイクル数) |
| TL | 260 | 21000 | TL | 300 | 10700 |
| L | 260 | 20000 | L | 300 | 15400 |
| TL | 230 | 31000 | TL | 280 | 23200 |
| L | 230 | 33000 | L | 280 | 22500 |
| TL | 230 | 33000 | TL | 260 | 25600 |
| L | 230 | 35000 | L | 260 | 22600 |
| TL | 230 | 35000 | TL | 240 | 30200 |
| TL | 210 | 47000 | L | 240 | 33000 |
| L | 210 | 51000 | TL | 222 | 58800 |
| TL | 180 | 131000 | L | 210 | 60800 |
| L | 180 | 140000 | TL | 200 | 95100 |
| TL | 160 | 279000 | TL | 190 | 101600 |
| L | 160 | 150000 | L | 190 | 110000 |
| TL | 150 | 15553000 | TL | 180 | 182800 |
| TL | 170 | 147000 | L | 180 | 190000 |
| L | 170 | 173000 | TL | 160 | 332000 |
| TL | 160 | 420000 | L | 160 | 700000 |
| L | 160 | 256000 | TL | 150 | 589700 |
| TL | 170 | 121000 | L | 150 | 434000 |
| L | 170 | 139000 | TL | 140 | 9567000 |
| TL | 160 | 234000 | L | 140 | 7834500 |

[0062]

[Table 6]

表 3 :

| 鋼板 3 | | 鋼板 9 | |
|------------------------------|--------------------|------------------------------|--------------------|
| Delta K (MPa \sqrt{m}) | da/dn (mm/サイクル) | Delta K (MPa \sqrt{m}) | da/dn (mm/サイクル) |
| 10 | 1.0E-04 | 10 | 2.0E-05 |
| 15 | 4.0E-04 | 15 | 1.0E-04 |
| 20 | 7.0E-04 | 20 | 6.0E-04 |
| 25 | 2.5E-03 | 25 | 2.0E-03 |

[0063]

[Table 7]

表 4 :

| 鋼 板 | | | 撓み (ミクロン) | | 機械的特性 | | |
|--------|-----|--------|--------------|------|----------|------------|-------|
| 鋼板 No. | 合 金 | e (mm) | fL | fTL | Rm (MPa) | R0.2 (MPa) | A% |
| 13 | A6 | 1.6 | 4000 | 3000 | 440 | 305 | 20.05 |
| 14 | A6 | 1.6 | 3000 | 4000 | 440.5 | 301.5 | 20.95 |
| 15 | A6 | 1.6 | 4000 | 3500 | 441 | 298.5 | 21.55 |
| 16 | A6 | 1.6 | 3500 | 3000 | 443 | 301 | 21.25 |
| 平 均 | | | 3625 | 3375 | 441.1 | 301.5 | 21.0 |
| 17 | A7 | 1.6 | 500 | 0 | 439.5 | 294 | 24.55 |
| 18 | A7 | 1.6 | 1500 | 1500 | 438.5 | 277.5 | 24.4 |
| 19 | A7 | 1.6 | 2000 | 1500 | 440 | 290 | 23.85 |
| 20 | A7 | 1.6 | 1000 | 0 | 441 | 289.5 | 25 |
| 平 均 | | | 1250 | 750 | 439.8 | 287.8 | 24.5 |

[0064]

[Table 8]

表 5 :

| 鋼 板 | | | 撓 み (ミクロン) | | 再結晶化率 | | | | 機 械 的 性 質 | | |
|--------|--------|----|---------------|-----|-------|------|----|---------|----------------|------------|----|
| 鋼板 No. | t (mm) | 合金 | FL | FTL | 表面 | 4分の1 | 中心 | 表面-中心の差 | TL Rm (MPa) | R0.2 (MPa) | A% |
| 21 | 12 | A8 | 240 | 480 | 90 | 90 | 67 | 23 | 465 | 335 | 15 |
| 22 | 12 | A8 | 710 | 90 | 100 | 99 | 97 | 3 | 470 | 339 | 15 |

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.

2.**** shows the word which can not be translated.

3. In the drawings, any words are not translated.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] An improvement of the processing stability of the direction of straight side (L) of a steel plate is shown.

[Drawing 2] An improvement of the processing stability of the direction of crossing-straight side (TL) of a steel plate is shown.

[Drawing 3] An isotropic improvement of the processing stability between the directions of L and the directions of TL in a steel plate is shown.

[Drawing 4] An improvement of the toughness of the direction of L-T of a steel plate is shown.

[Drawing 5] An improvement of the toughness of the direction of T-L of a steel plate is shown.

[Drawing 6] An improvement of the toughness of the direction of S-L of a steel plate is shown.

[Drawing 7] A fatigue-resistant result is shown.

[Drawing 8] The improvement about a crack rate is shown.

[Drawing 9] An improvement of the elongation of the direction of TL of sheet steel is shown.

[Drawing 10] An improvement of the processing stability of sheet steel is shown.

[Drawing 11] The result related with the processing stability of an inside steel plate is shown.

[Drawing 12] The result related with the crack rate of an inside steel plate is shown.

[Translation done.]

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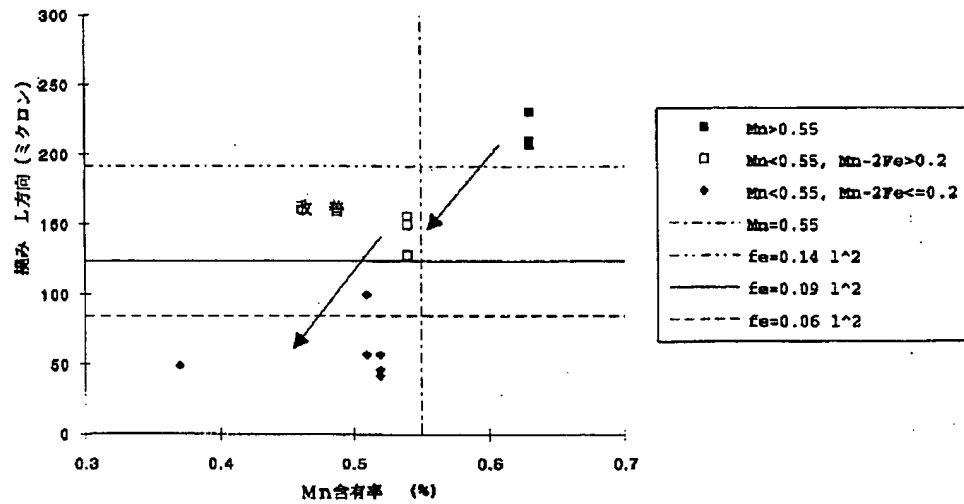
2. **** shows the word which can not be translated.

3. In the drawings, any words are not translated.

DRAWINGS

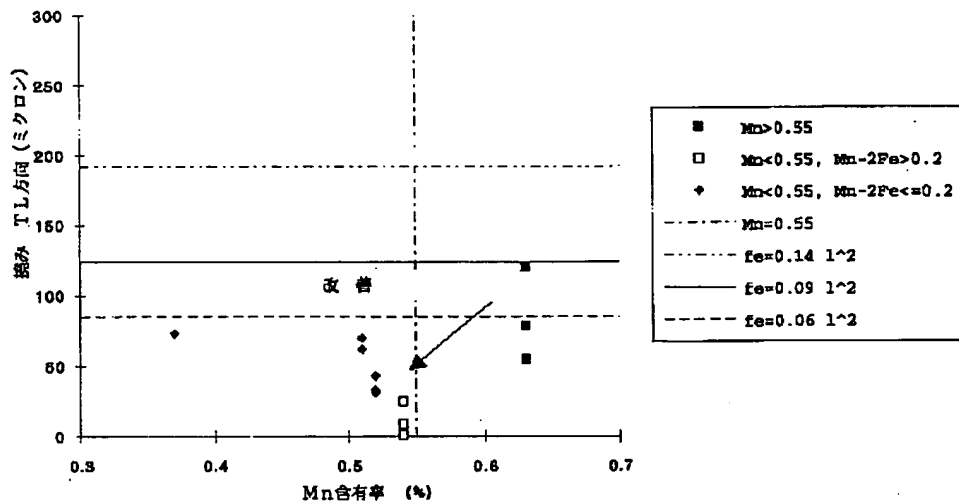
[Drawing 1]

図1 : 長手 (L) 方向の加工安定性の改善



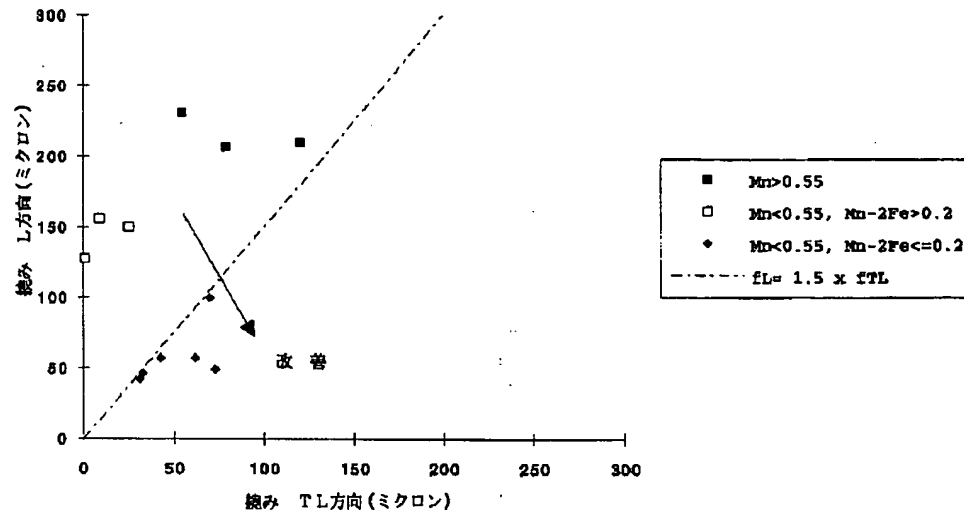
[Drawing 2]

図2 : 横断-長手 (TL) 方向の加工安定性の改善



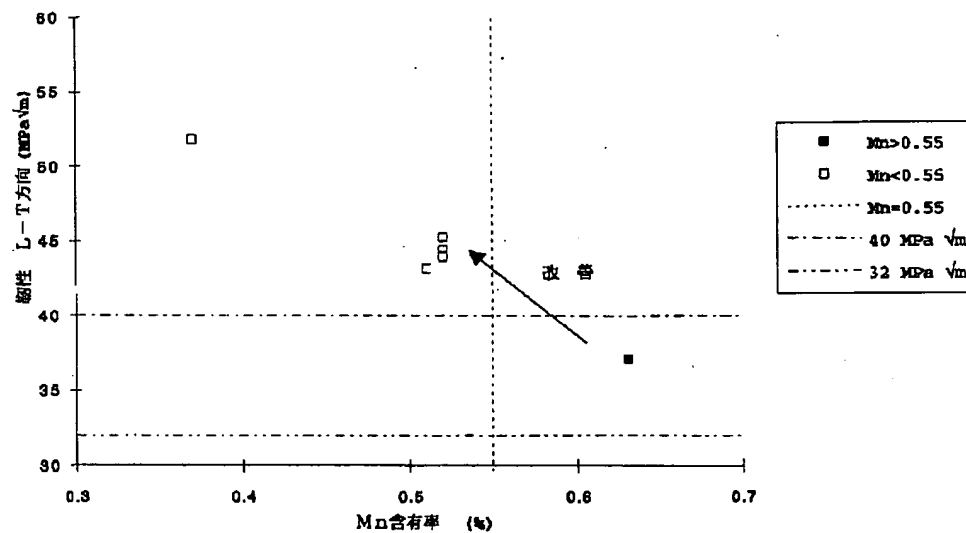
[Drawing 3]

図3 : 加工安定性の等方性の改善



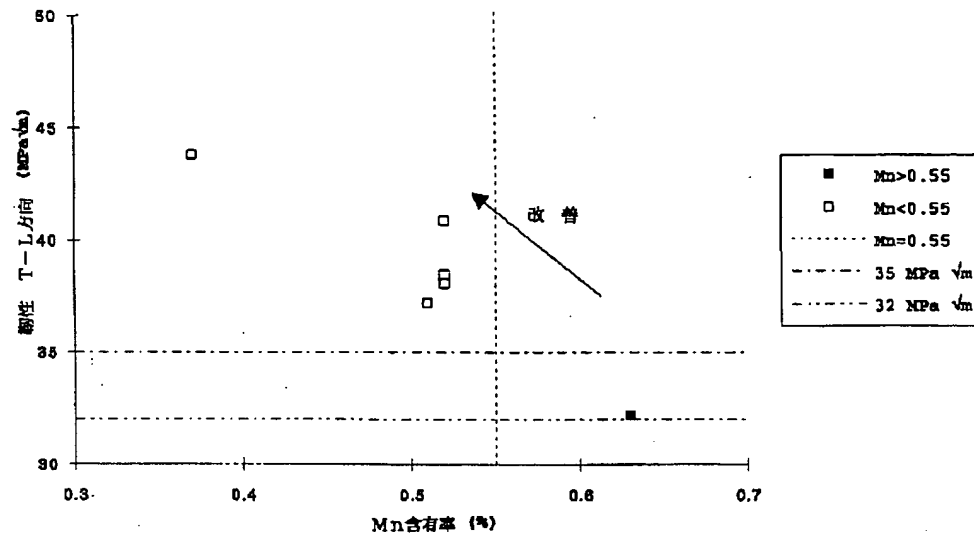
[Drawing 4]

図4 : L-T方向の韌性の改善



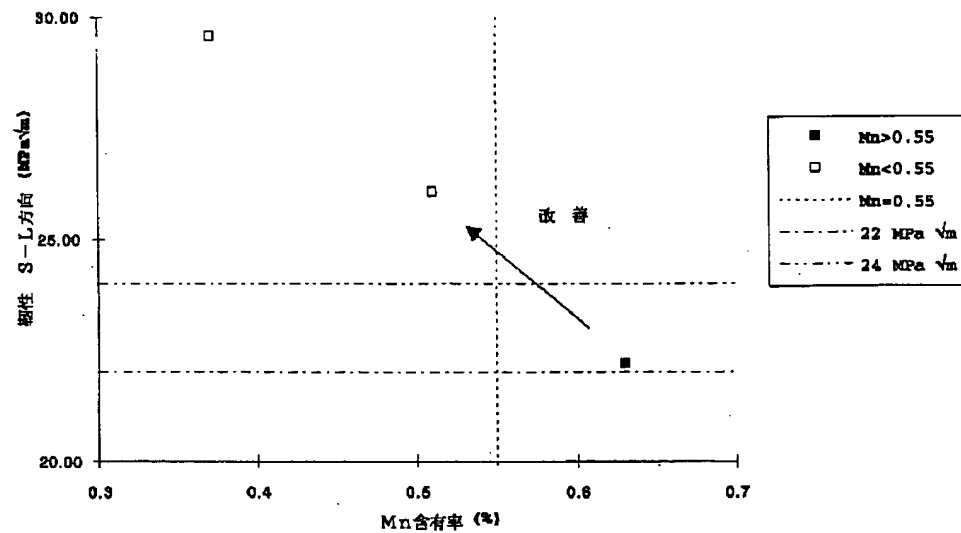
[Drawing 5]

図5 : T-L方向の靱性の改善

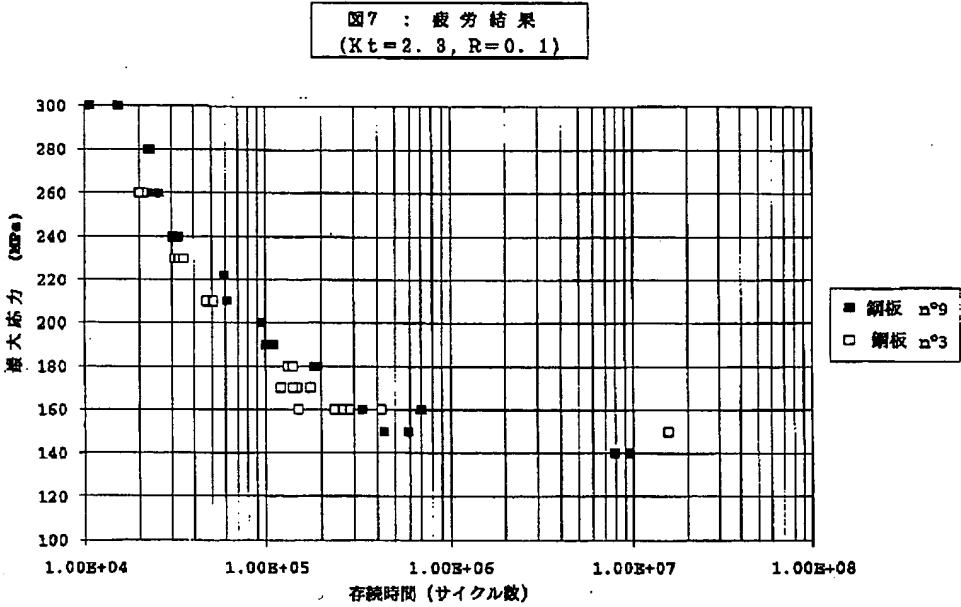


[Drawing 6]

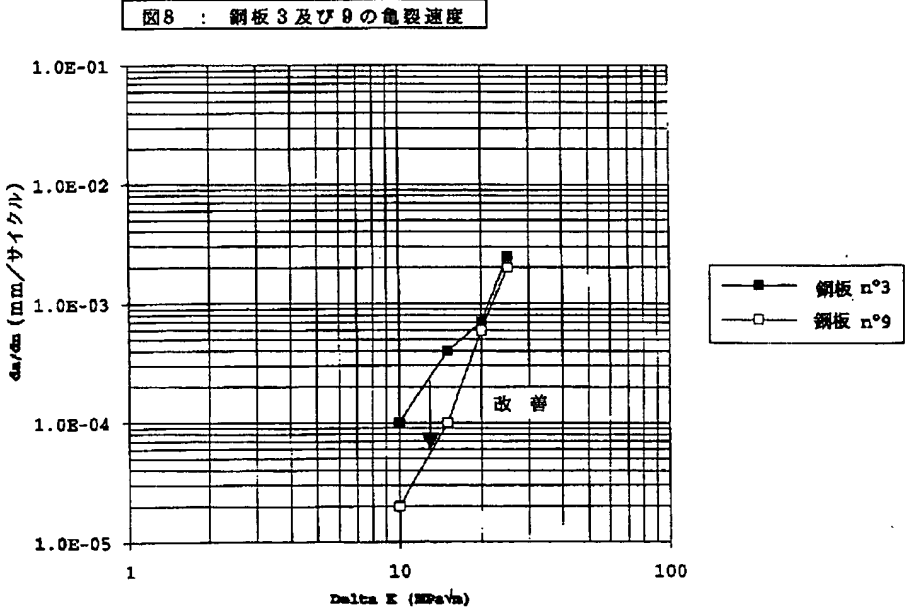
図6 : S-L方向の靱性の改善



[Drawing 7]

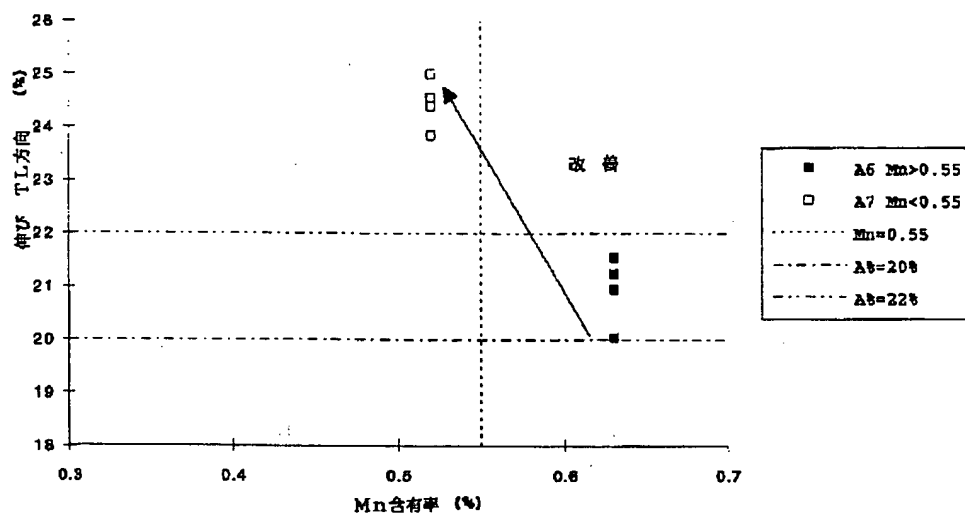


[Drawing 8]



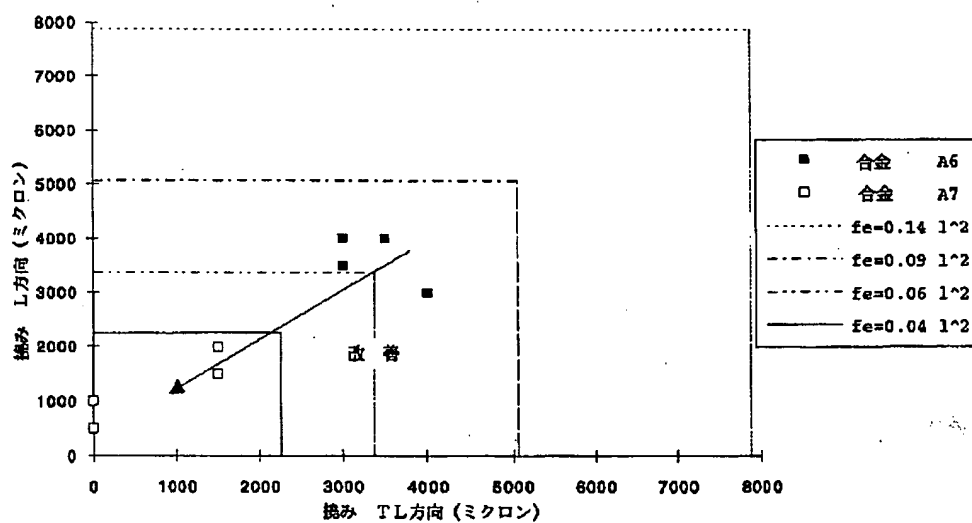
[Drawing 9]

図9 : 薄鋼板 (1.6mm) のT-L方向の伸びの改善



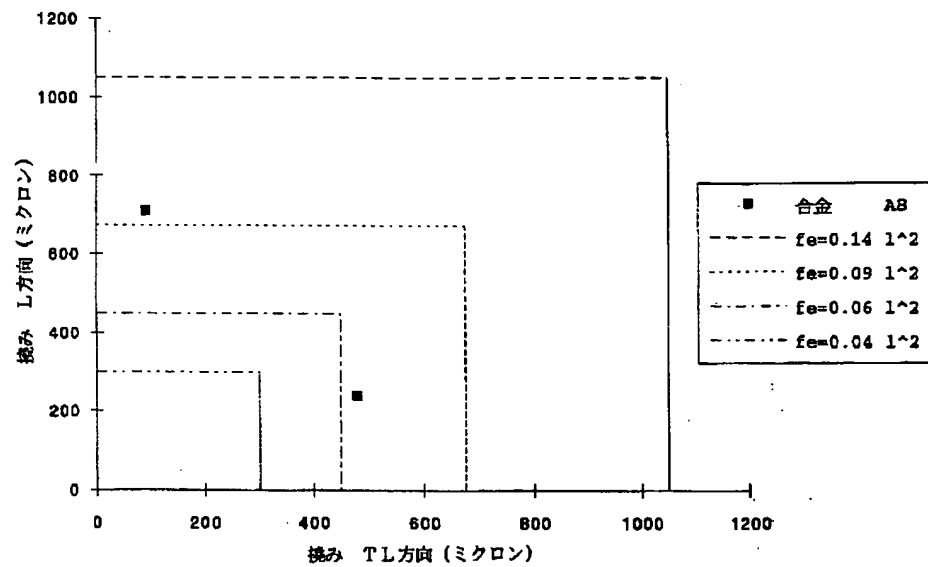
[Drawing 10]

図10 : 薄鋼板 (1.6mm) の加工安定性の改善



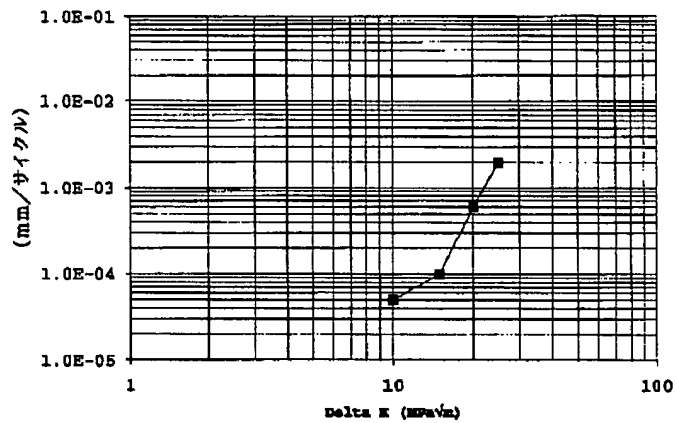
[Drawing 11]

図11 : 中鋼板 (12mm) の加工安定性



[Drawing 12]

図12 : 亀裂速度



[Translation done.]